

Course "Softwaretechnik"
Book Chapter 4
Requirements Elicitation
(Anforderungserhebung)

Lutz Prechelt, Steve Easterbrook

Freie Universität Berlin, Institut für Informatik
<http://www.inf.fu-berlin.de/inst/ag-se/>

- Requirements and Requirements Engineering
- Kinds of requirements
- Requirements and modeling
- Hard and soft systems
- Requirements Elicitation
 - identify problem & opportunity
- Elicitation techniques
 - Conventional
 - Representation-based
 - Social
 - Knowledge elicitation

Where are we?: Taxonomie "Die Welt der Softwaretechnik"

Welt der Problemstellungen:

- **Produkt (Komplexitätsprob.)**
 - **Anforderungen (Problemraum)**
 - Entwurf (Lösungsraum)
- Prozess (psycho-soziale P.)
 - Kognitive Beschränkungen
 - Mängel der Urteilskraft
 - Kommunikation, Koordination
 - Gruppendynamik
 - Verborgene Ziele
 - Fehler

Welt der Lösungsansätze:

- Technische Ansätze ("hart")
 - Abstraktion
 - Wiederverwendung
 - Automatisierung
- **Methodische Ansätze ("weich")**
 - **Anforderungsermittlung**
 - Entwurf
 - Qualitätssicherung
 - Projektmanagement

Where are we?: Anforderungsermittlung

- Einsicht: Man darf sich nicht auf intuitiven Eindruck darüber verlassen, was gebaut werden sollte
 - sondern sollte die Anforderungen systematisch ermitteln
- Prinzipien:
 - **Erhebung** der Anforderungen bei allen Gruppen von Beteiligten
 - **Beschreibung** in einer Form, die die Beteiligten verstehen
 - **Validierung** anhand der verschriftlichten Form
 - **Spezifikation**: Übertragung in zur Weiterverarbeitung günstige Form
 - **Trennung von Belangen**: Anford. möglichst wenig koppeln
 - **Analyse auf Vollständigkeit**: Lücken aufdecken und schließen
 - **Analyse auf Konsistenz**: Widersprüche aufdecken und lösen
 - **Mediation**: Widersprüche, die auf Interessengegensätzen beruhen, einer Lösung zuführen (Kompromiss oder Win-Win)
 - **Verwaltung**: Übermäßige Anforderungsänderungen eindämmen, Anforderungsdokument immer aktuell halten

- What is a Requirement?

- Something that someone needs in order to solve a problem or achieve an objective:
 - *"A condition or capability that must be met or possessed by a system or system component to satisfy a contract, standard, specification, or other formally imposed document.*
The set of all requirements forms the basis for subsequent development of the system or system component". [IEEE Std]
- Note 1: Often, the "formally imposed document" does not exist, but there is still *somebody* wishing to be satisfied.
 - Informal requirements
- Note 2: Often, what is written down in the "formally imposed document" will not really *satisfy* the system user
 - Invalid/incorrect requirements
- Note 3: Requirements are definitions, **not facts**.
- Note 4: "System" can be a computer system (**system req's**) or a socio-technical system (**user requirements**)

Definitions:

Types of Requirements

- Functional requirements:
 - What the system does: the interactions between the system and its environment; independent from implementation
- Nonfunctional requirements:
 - Observable aspects of the system that are not directly related to functional behavior
 - e.g. performance or reliability aspects, etc.
- Safety/security requirements ("shall not" properties)
 - A kind of nonfunctional requirement:
Behavior the system must never exhibit
 - e.g. "must be impossible to apply reverse thrust in mid-flight"
- Constraints ("Pseudo requirements"):
 - Imposed by the client or environment in which the system operates
 - Often concern the technology to be used (language, operating system, middleware etc.)

nonfunctional requirements

Definitions: Requirements Engineering (RE)

- Requirements Elicitation is part of Requirements Engineering
- Requirements Engineering (RE):

"[...] **Requirements Engineering** is the **branch of systems engineering** concerned with **real-world goals** for, services provided by, and constraints on software systems. Requirements Engineering is also concerned with the relationship of these factors to **precise specifications** of system behaviour and to their **evolution** over time and across system families..."
[Zave94]

"[...] RE is concerned with **identifying the purpose** of a software system, and **the contexts** in which it will be used." [RE'01 CfP]

1. Understand the problem

- Requirements Elicitation
- understand the context and the goals in the user's terms

2. Formally describe the problem

- Requirements Specification
- describe what the SW must do to reach the goals

3. Attain agreement on the problem

- Requirements Validation
- find gaps, mistakes, and inconsistencies in the requirements
- includes conflict resolution, negotiation

4. Maintain the agreement

- Requirements Management
- negotiate and decide on changes of the specification

Conflict is natural and ubiquitous

- Even the most cooperative stakeholders ("Beteiligte") will inevitably have conflicts
- Conflict resolution is a core activity of RE



Requirements Validation

- Even without conflict, requirements validation is a critical step in the development process
 - after requirements engineering or requirements analysis
 - and again at delivery
- Requirements validation criteria:
 - Correctness:
 - The requirements accurately represent the client's view.
 - Completeness:
 - All possible scenarios in which the system can be used are described, including exceptional behavior by the user or the system
 - Consistency:
 - No functional or nonfunctional requirements contradict one another
 - Feasibility/Realism:
 - Requirements can realistically be implemented and delivered
 - Traceability:
 - It will be possible to trace each system function to a corresponding (set of) functional requirement(s)

- Problem with requirements validation:
Requirements change during and after elicitation
- Large projects need tool support to manage requirements:
 - Store requirements in a shared repository
 - Provide multi-user access
 - Automatically create a system specification document from the repository
 - Allow change management
 - Provide traceability throughout the project lifecycle
- e.g. IBM Rational DOORS
- e.g. an appropriate Wiki tool (for not-so-huge projects)



- **Domain Properties** are properties in the problem domain that are true whether or not we ever build the proposed system
- **Requirements** are properties in the problem domain that we wish to be made true by delivering the proposed system
- **A specification** is a description of the behaviors of the program in the solution domain that the program must have in order to meet the requirements
 - The system specification (system requirements), not to be confused with a statement of the requirements themselves, the requirements specification (user requirements)

Validation vs. Verification

- Verification checks the equivalence of different formal representations
- Validation checks if a system fulfills the actual expectations in the real world
- **Verification** criteria:
 - Does the **Program** running on a particular **Computer** satisfy the **Specification**?
 - (perhaps also:) Does the **Specification**, in the context of the given **Domain properties**, satisfy the *stated* **Requirements**?
- **Validation** also checks:
 - Did we understand all the important **Requirements**?
 - Did we understand all the relevant **Domain properties**?

Validation example

- Requirement R:
 - "Reverse thrust shall only be enabled when the aircraft is moving on the runway"
- Domain Properties D:
 - Wheel pulses are on if and only if wheels are turning
 - Wheels are turning if and only if aircraft is moving on runway
- Specification S:
 - Reverse thrust is enabled if and only if wheel pulses are on
- $S + D$ imply R
 - But what if the domain model D is wrong?

(Do you recognize the example?)

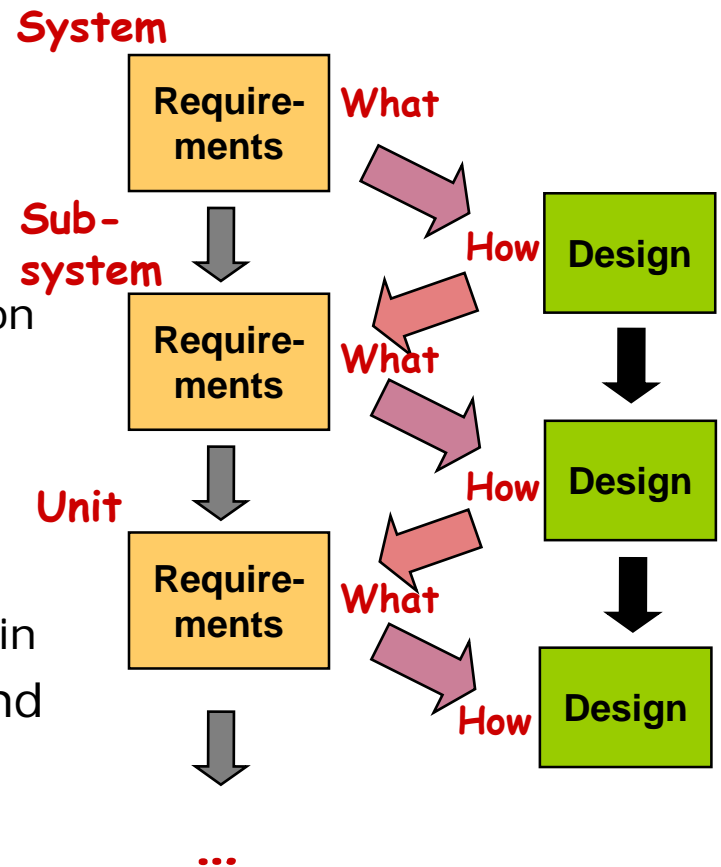


Another validation example

- Requirement R:
 - "The database shall only be accessible by authorized personnel"
- Domain Properties D:
 - Authorized personnel have passwords
 - Non-authorized personnel do not have passwords
- Specification S:
 - Access to the database shall only be granted after the user types an authorized password
- $S + D$ imply R
 - But what if the domain assumptions are wrong?

What vs. How

- Traditionally, Requirements should specify 'what' without specifying 'how'
 - But this is not always easy to distinguish:
 - What does a car do vs. a bike?
 - (Don't mention the motor: 'how!')
 - The 'how' at one level of abstraction forms the 'what' for the next level
- A suitable distinction
 - 'What' refers to a system's purpose
 - it is **external** to the system
 - it is a property of the application domain
 - 'How' refers to a system's structure and behavior
 - it is **internal** to the system
 - it is a property of the solution domain



What is a **System**?

Definition of a System:

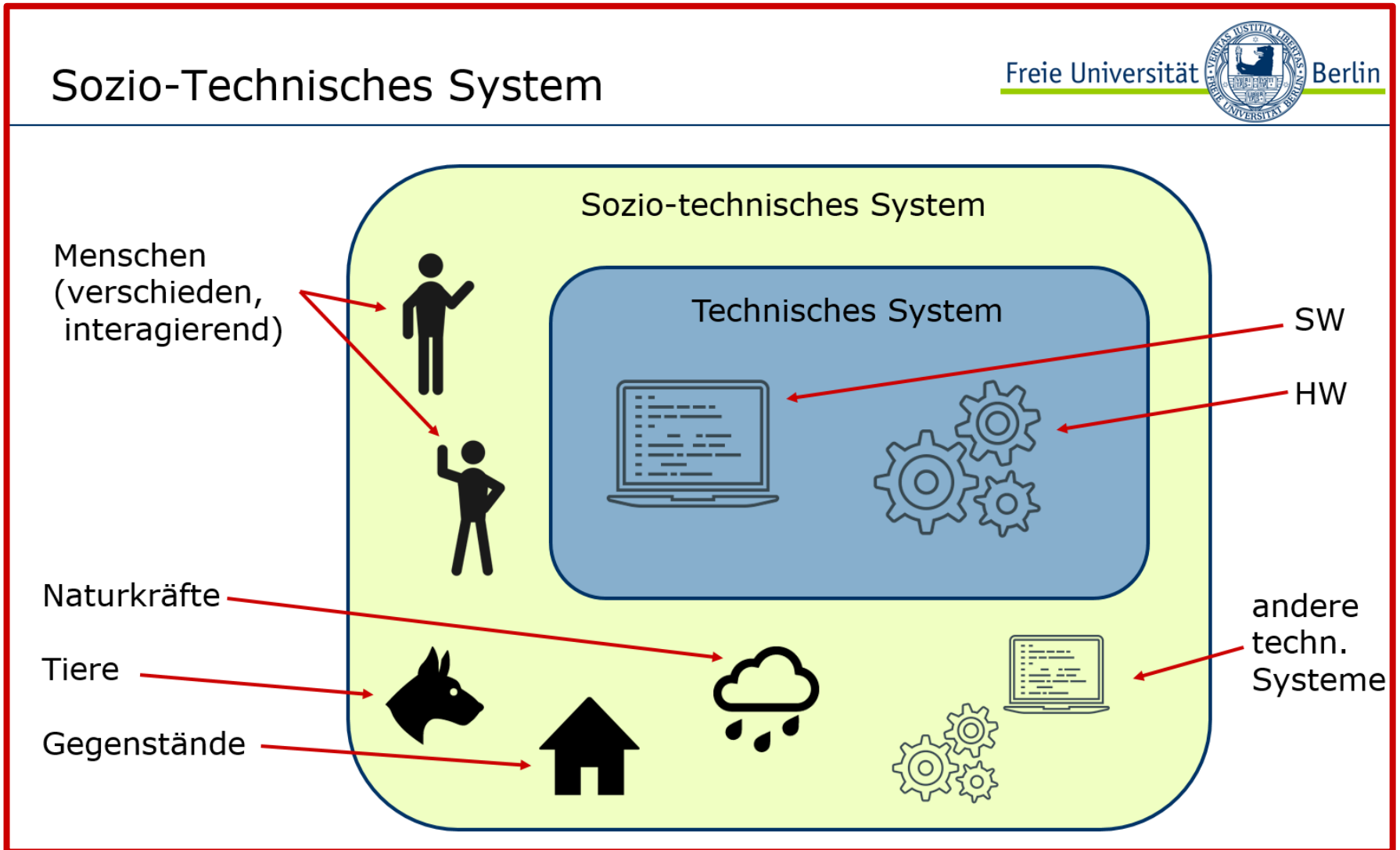
- Some part of reality that can be observed to interact with its environment
 - Separated from its environment by a **boundary**
 - Boundary may be difficult to decide: **"soft" system**
 - A system receives **inputs** from the environment and sends **outputs** to the environment
 - Many systems have a **control mechanism**
 - Most systems have interesting **emergent properties**
- Examples:
 - cars, cities, houseplants, rocks, spacecraft, buildings, weather, ...
 - operating systems, DBMS, The Sims, Instagram, the Internet
- Non-examples (there aren't many!):
 - numbers, truth values, letters

Most systems are "soft"

- The software we will eventually write is not "the system" with respect to requirements engineering
 - The software is the system only in the solution domain
 - but not in the problem domain
- Rather, other things are also part of the system in the problem domain:
 - the people using the software,
 - the ways in which they use it,
 - many other environmental factors
- This larger system we need to understand during requirements elicitation
 - Rule of thumb: If people are involved in any way, never confuse the software with the system
 - Remember "Auswirkungen d. Informatik"?:
underground train with taped-down "GO" button?
 - Very simple software, but a surprising system



Sozio-Technisches System



- Starting point: Some notion that there is a "problem" that needs solving
 - e.g. dissatisfaction with the current state of affairs
 - e.g. a new business opportunity
 - e.g. a potential saving of cost, time, resource usage, etc.
- The requirements engineer must:
 - become enough of an expert in the problem domain to
 - identify the problem and opportunity and
 - elicit enough knowledge to analyze requirements for
 - validity, consistency, and completeness

W6H

The journalist's technique:

What?

Where?

Who?

Why?

When?

How?

(Which?)

Identifying the problem and opportunity

- Which problem needs to be solved?
 - identify problem **Boundaries**
- Where is the problem?
 - understand the **Context/Problem Domain**
- Whose problem is it?
 - identify **Stakeholders (Betroffene, Beteiligte)**
- Why does it need solving?
 - identify the stakeholders' **Goals**
- How might a software system help?
 - collect some **Scenarios**
- When and how does it need solving?
 - identify **Development Constraints**
- What might prevent us solving it?
 - identify **Feasibility** and **Risk**

Very
useful slide

W6H

The journalist's technique:

What?

Where?

Who?

Why?

When?

How?

(Which?)

Difficulties of Elicitation (1)

- Limited observability
 - The problem owners might be too busy solving it in its current form
 - Presence of an observer may change the problem
- Bias
 - People may not be free to tell you what you need to know
 - Political climate & organizational factors
 - People may not want to tell you what you need to know
 - The outcome will affect them, so they may try to influence you (hidden agendas)
- There will be conflicts between different sources
 - People have conflicting goals
 - People have different understandings
- Thin spread of domain knowledge
 - It might be distributed across many sources
 - Is rarely available in explicit form

Difficulties of Elicitation (2): Tacit knowledge

- Tacit knowledge
(The "say-do" problem)
Three stage model of learning:
 - 1) cognitive – verbal rehearsal of tasks
 - 2) associative – with repetition, verbal mediation disappears
 - 3) autonomous – no conscious awareness of performance.

➔ Experts are not aware of what they know and cannot introspect reliably
- Representational Problems
 - Experts don't have the language to describe their knowledge
 - Spoken language lacks necessary precision
 - Knowledge Engineer and Expert must work together to create a suitable language and representation formalism
 - Different knowledge representations are good for different things
- Brittleness
 - Knowledge is created, not extracted: incomplete, overly simplified

Difficulties of Elicitation (3): Distortions

Sender-related:

- Social pressure
 - Response to verbal and non-verbal cues from an interviewer
- Group think
 - Response to reactions of other experts
- Impression management
 - Response to imagined reactions of managers, clients, etc.
- Wishful thinking
 - Response to hopes
- Availability
 - Some data are easier to recall than others
- Underestimation of uncertainty
 - Tendency to underestimate by a factor of 2 or 3

Receiver-related:

- Misinterpretation
 - due to lack of knowledge
- Misrepresentation
 - Expert cannot accurately fit a response into the requested response mode
- Anchoring
 - Contradictory data is ignored once an initial solution is available

Sender- and receiver-related:

- Inconsistency
 - Statements made earlier are forgotten

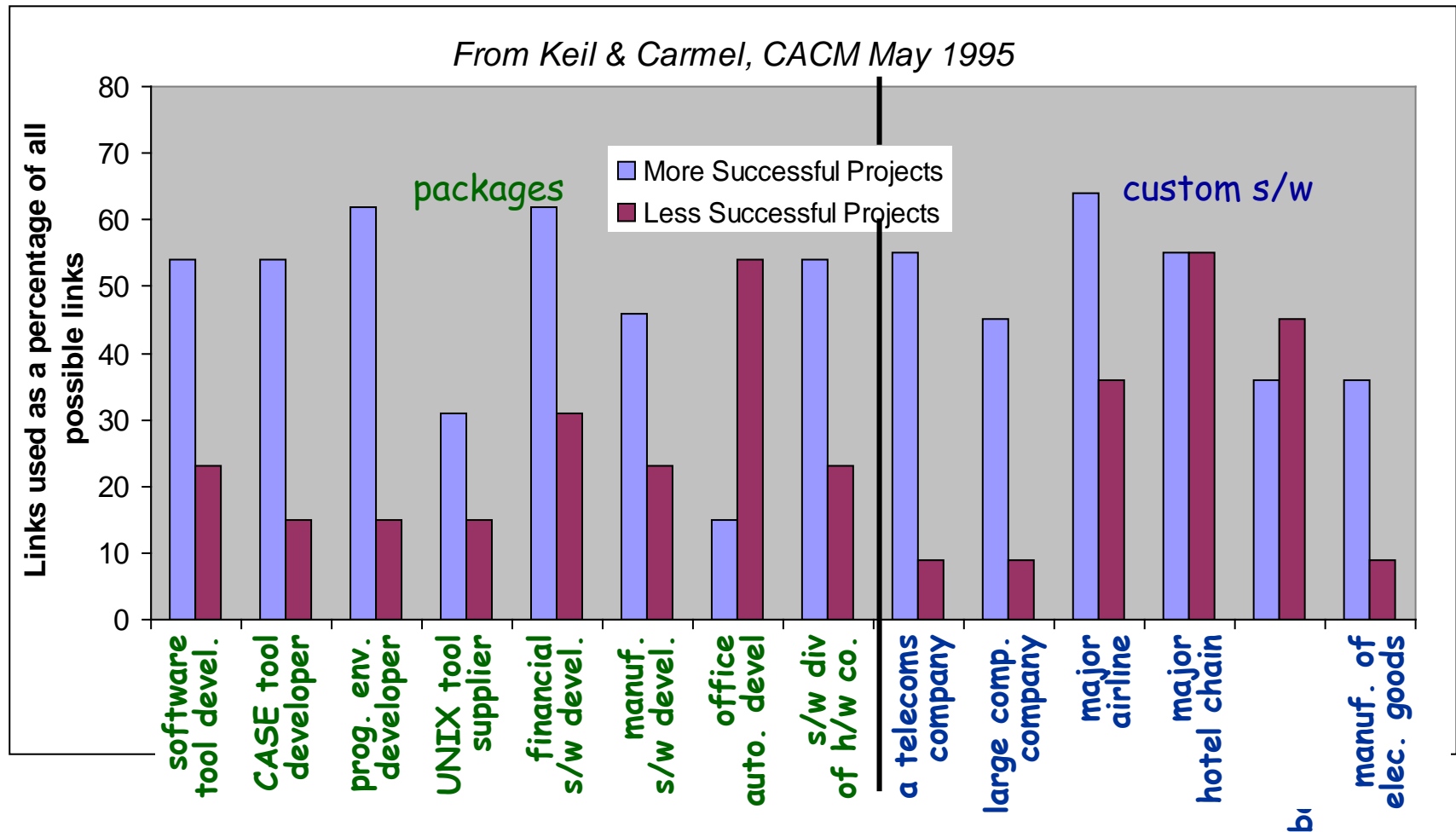
Difficulties of Elicitation (4)

- Personal and interpersonal factors



Importance of links with customer(s)

- Successful projects tend to have more customer links



- Traditional Approaches
 - Introspection
 - Existing Documents/Data
 - Interviews
 - Open-ended
 - Structured
 - Surveys/Questionnaires
 - Group elicitation
 - Focus Groups
 - Brainstorming
 - JAD/RAD workshops
 - Prototyping
- Representation-based approaches
 - Goal-based
 - Scenario-Based
 - Use Cases

- Contextual (social) appr.
 - Ethnographic techniques
 - Participant Observation
 - Ethnomethodology
 - Discourse Analysis
 - Conversation Analysis
 - Speech Act Analysis
 - Participatory Design
 - Sociotechnical Methods
 - Soft Systems Analysis
- Cognitive approaches
 - Task analysis
 - Protocol analysis
 - Knowl. Acquisition Technqqs
 - Card Sorting
 - Laddering
 - Repertory Grids
 - Proximity Scaling

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Method: Introspection

- Just sit down and think what the requirements may be
 - Very popular with software engineers
 - But then often in the form:
Just sit down and think up some requirements
- Advantages
 - Simple, quick, cheap, no misunderstandings
- Disadvantages
 - Often not applicable ("I have no idea")
 - **Can be extremely misleading**
 - (The mantra of usability people is: "Users are not like us!")

- Identify Collections of existing Hard Data
 - Facts and figures, financial information,...
 - Reports used for decision making,...
 - Survey results, marketing data,...
- Advantages
 - Can be quick and cheap
 - Sometimes offers very detailed information
- Disadvantages
 - **Most often not applicable**
 - Data may be biased
 - Data may be outdated

- Types:
 - Structured – agenda of fairly open questions
 - Open-ended – no pre-set agenda
- Advantages
 - Rich collection of information
- Disadvantages
 - **Interviewing is a difficult skill to master**
 - Large amount of qualitative data can be hard to analyze
 - Hard to compare different respondents
- Watch for
 - Tacit knowledge (and post-hoc rationalizations)
 - Removal from context
 - Influence from interviewer's attitude

- Advantages
 - Can quickly collect info from large numbers of people
 - Can be administered remotely
 - Can collect attitudes, beliefs, characteristics
- Disadvantages
 - Simplistic (presupposed) categories provide very little context
 - No room for users to convey their real needs
- Watch for:
 - Bias in sample selection (especially with self-selection)
 - Too-small sample size
 - Suggestive questions → answers will be biased
 - Ambiguous questions → not everyone answers the same question
 - Questionnaires **MUST** be prototyped and tested

- Types:
 - Joint/Rapid Application Development (JAD/RAD) Workshops
 - Focus Groups
 - Brainstorming
- Advantages
 - More natural interaction between people than formal interview
 - Can gauge group reaction to mock-ups, storyboards, etc.
- Disadvantages
 - May create unnatural groups (uncomfortable for participants)
 - **Danger of Groupthink**
 - May only provide superficial responses where detail is needed
 - Requires a highly trained facilitator
- Watch for
 - Sample bias
 - Dominance and submission



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Goal-based approaches

- Approach

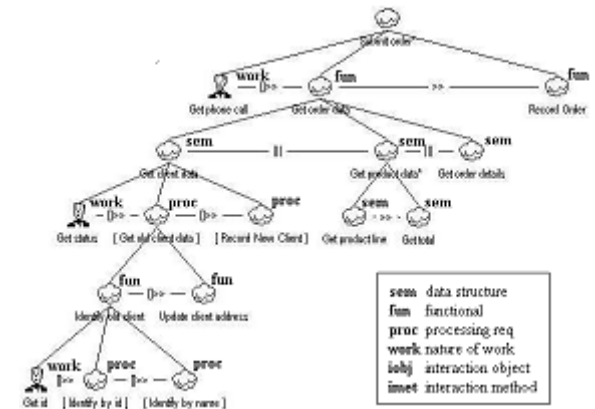
- Focus on why systems are constructed
- Express the 'why' as a set of stakeholder goals
 - The top-level goal is often "save money" or "make money"
 - Use goal refinement to arrive at specific requirements
- Goal analysis: document, organize and classify goals
- Goal hierarchies show refinement and obstacle relationships between goals

- Advantages

- Reasonably intuitive
- **Sound basis for conflict resolution**

- Disadvantages

- Hard to cope with evolution of goals
- **Either very complex goal hierarchy (can lead to analysis paralysis) or lack of detail**



- Scenarios
 - Specific sequence of interaction between actor and system
 - typically between 3 and 7 steps
 - May be:
 - positive (i.e. required behavior)
 - negative (i.e. an undesirable interaction)
 - Often used as a first step when writing use cases
- Advantages
 - Very natural: stakeholders tend to use them spontaneously
 - Short scenarios very good for quickly illustrating specific interactions
- Disadvantages
 - Lack of structure: need use cases or task models to provide higher-level view

- What is a use case?
 - A description of a sequence of actions that a system performs that yields an observable result of value to a particular actor
 - i.e. a description of a set of possible concrete scenarios that have a common purpose
 - Typically written in natural language
- Advantages
 - Easy to write, easy to understand (natural representation)
 - Helps in drawing system boundary
- Disadvantages
 - Use cases do not represent nonfunctional requirements
 - **Use cases do not capture domain knowledge**
 - Sometimes confused with a precise specification

UC_23 - eVerordnung_erstellen_Abschnitt_3	
Beschreibung	Die Informationen für eine eVerordnung werden zusammengestellt und signiert. Die eVerordnung wird auf eGK oder VODD verschoben.
Anwendungsumfeld	Institution des Akteurs Arzt (z. B. Arztpraxis, Krankenhaus)
Vorbedingungen	<ul style="list-style-type: none">• Regelmäßige Nutzung der eGK ist überprüft.• technisch nutzbare eGK liegt vor (gemäß [gemFK_CMSeGK_Nutz]).• Zugriffsauthentisierung durch Akteure ist erfolgt.
Auslöser	Eine eVerordnung soll erstellt werden.
Eingangsdaten	VSD_eGK / VOD_AM / Signaturdaten
Ergebnisse	Die eVerordnung wurde auf VODD oder eGK gespeichert.
Nachbedingungen	Die eVerordnung steht auf VODD oder eGK bereit zur weiteren Verwendung.
Beteiligte Akteure	- Arzt - Mitarbeiter medizinische Institution]
Geschäftsobjekte	eVerordnung
Standardablauf	1 [Arzt oder Mitarbeiter medizinische Institution]: Informationen für die eVerordnung zusammenstellen 2 [Arzt]: Informationen der eVerordnung anzeigen (zur Signatur) 3 [Arzt]: Informationen der eVerordnung signieren 4 [Arzt oder Mitarbeiter medizinische Institution]: Schlüssel für die

Note: Beware of natural language!

- Natural language is easy-to-use, natural, and often appropriate for describing requirements
- But it is rarely precise!
- Example:
"Buffalo once roamed the plains in large numbers"



Buffalo once roamed the plains in large numbers.

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The ethnomethodologist's view

Requirements elicitation is a social activity

- Because it involves people-to-people communication
 - through discussions, observation, etc.
- Because it involves negotiation in bringing about consensus when there is disagreement.
- Because it affects and changes human activity systems

The domain of application is often a social world

- Need techniques that uncover the order of the social world
 - Social order might not be immediately obvious or describable
 - Social order cannot be assumed to have an *a priori* structure
- **Social order can only be understood through immersion**
 - Social order is constructed by the participants' actions
 - Need to witness the unfolding of social phenomena
 - Cannot just collect data using pre-given categories

- Assumptions
 - Social world is ordered
 - We cannot know the order a-priori
 - To understand it, we need to immerse in its natural setting
- Categories
 - Most conventional approaches assume preexisting categories
 - This may mislead the observer (appropriation)
 - Ethnography attempts to use the subjects' own categories
 - Related to postmodern deconstruction: "there is no grand narrative"
- Measurement
 - There is no scientific objectivity about social phenomena
 - We need to use the subjects' own measurement theory

Method: Participant observation ("teilnehmende Beobachtung")

- Approach
 - Observer spends time with the subjects, joining in, long enough to become a member of the group ('longitudinal studies')
- Advantages
 - Highly contextualized and relatively reliable
 - Reveals details that other methods cannot
- Disadvantages
 - **Extremely time consuming!**
 - Resulting 'rich picture' is hard to analyze
 - Cannot say much about the results of proposed changes
- Watch for
 - going native!



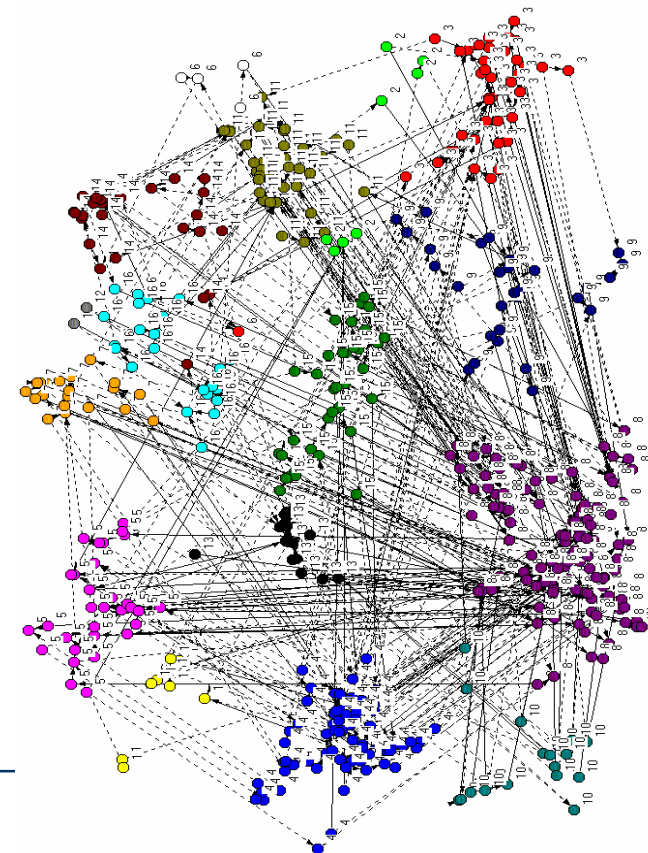
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Method: Protocol Analysis

- Based on protocols created from vocalizing behavior
 - either "think-aloud" or retrospective
- Analyze protocols to reveal requirements
- Advantages
 - Direct verbalization of cognitive activities
 - Embedded in the work context
 - Good at revealing interaction problems with existing systems
- Disadvantages
 - **Interpretation requires introspection, hence unreliable**
 - No social dimension

- Given some domain objects, derive a set of dimensions for classifying them:
 - Step 1: pairwise proximity assessment among domain elements
 - captures tacit knowledge of expert
 - Step 2: automated statistical analysis to build multi-dimensional space to classify the objects
- Advantages
 - Helps to elicit mental models where complex multivariate data is concerned
 - **Good for eliciting tacit knowledge**
- Disadvantages
 - Requires an agreed-upon set of objects
 - Only models classification knowledge, **not performance knowledge**



Method: Card sorting

- For a given set of domain objects, written on cards:
 - Expert sorts the cards into groups...
 - ...then says what the criterion was for sorting, and what the groups were

- Advantages

- Simple, amenable to automation
 - Elicits classification knowledge
- **Good for eliciting tacit knowledge**

- Disadvantages

- Requires an agreed-upon set of objects
- Only models classification knowledge, **not performance knowledge**

Airport classification criteria proposed by CASA



Data from [CASA](#)

- **Requirements** represent the goals to be reached via a software system
- A **specification** describes what the software must do in order to fulfill the requirements
 - assuming certain domain properties are met
- Requirements **elicitation** is the basic step of **Requirements Engineering**
 - others are Req. Specification, Req. **Validation**, and Req. **Management**
- Requirements Elicitation must overcome many recurring problems
- Many different elicitation **techniques** should be combined

- James Robertson, Suzanne Robertson: "Mastering the Requirements Process: Getting Requirements Right", 3rd ed., Addison-Wesley 2012
- Donald Gause, Gerald Weinberg: "Exploring Requirements – Quality before Design", B&T, 1989
 - auf deutsch: "Software Requirements: Anforderungen erkennen, verstehen und erfüllen", (vergriffen)
 - <http://www.geraldmweinberg.com>

Thank you!